AR-009-740

DSTO-GD-0097

# Annotated Bibliography of Helmet Mounted Sight Systems

A.J. Saliba and J.W. Meehan

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DEPARTMENT OF DEFENCE
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*A. J. Saliba and J.W. Meehan*

**Air Operations Division**
**Aeronautical and Maritime Research Laboratory**


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## ABSTRACT

A search of literature was conducted on helmet mounted sights (HMSs) and related helmet mounted displays (HMDs). The result was 42 entries that are grouped under broad subject headings of human factors, design and evaluation, and other related areas. Human factors deals with issues relating to human performance with HMSs and HMDs. Design and evaluation covers work that is focused more on the helmet systems. Work in related areas includes material that fits neither of the other categories, but which is relevant. Entries are accompanied by an abstract, annotation, or both. This bibliography represents present understanding of issues involved with the current state of technology. Rapid growth in computer technology suggests that developments in this area will accelerate rapidly, indicating a need for maintaining commensurate research effort in human performance in the virtual environments that this technology is providing.


**RELEASE LIMITATION**

*Approved for public release*




DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

*Published by*

*DSTO Aeronautical and Maritime Research Laboratory*
*PO Box 4331*
*Melbourne Victoria 3001*

*Telephone: (03) 9626 8111*
*Fax: (03) 9626 8999*

*AR-009-740*
*January 1996*

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## Executive Summary

A search of literature was conducted on helmet mounted sights (HMSs) and related helmet mounted displays (HMDs). The result was 42 entries that are grouped under broad subject headings of human factors, design and evaluation, and other related areas. Human factors deals with issues relating to human performance with HMSs and HMDs. Design and evaluation covers work that is focused more on the helmet systems. Work in related areas includes material that fits neither of the other categories, but which is relevant. Entries are accompanied by an abstract, annotation, or both. This bibliography represents present understanding of issues involved with the current state of technology. Rapid growth in computer technology suggests that developments in this area will accelerate rapidly, indicating a need for maintaining commensurate research effort in human performance in the virtual environments that this technology is providing.

# Authors

**Anthony Saliba**
Air Operations Division

*Anthony Saliba is a professional officer working in the human factors technology field with the Air Operations Division of DSTO. He has a B.Sc. (Hons) degree from Deakin University in physiology and biology, with an extended major in psychology. At the completion of his undergraduate degree, Mr. Saliba was awarded a Vacation Scholarship at The University of Tasmania, where he gained experience in EEG recording and scoring techniques. His honours thesis examined the effect of the torso on auditory localisation. After completing honours, Mr Saliba tutored at Deakin University, and while there he was involved in research into localisation of virtual sounds. He also has human factors experience working at the Australian National University, principally in human-computer interaction, and in psychophysiology, specifically in recording cardiovascular responses to simulated tasks. At present he is involved in the determination of sound pressure levels in the Black Hawk and Seahawk helicopters and the evaluation of various sound attenuation devices, including active noise reduction.*

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**James Meehan**
Air Operations Division

*James Meehan holds bachelor degrees in Economics, Arts and Science (Honours), and in 1990 was awarded a Ph.D. in experimental psychology at Monash University. In 1991 he was awarded a French Government Scientific Fellowship at Centre d'Etudes et de Recherches de Médecine Aérospatiale in Paris where he conducted research in 3-D cockpit displays. On return to Australia he worked on visual discrimination of skin lesions and computer imaging of melanoma at the Anti-Cancer Council of Victoria. He is Honorary Academic Associate of the Centre for Behavioural Research in Cancer, Member of the Australian Psychological Society, and Member of the Human Factors and Ergonomics Society (USA). He joined Air Operations Division in 1994, and works in the Air Operations Simulation Centre in the human factors technology field, with a special interest in perceptual and cognitive distortions that occur in virtual environments.*

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# CONTENTS

## 1. INTRODUCTION

A search of literature was conducted on helmet mounted sights (HMSs) and related helmet mounted displays (HMDs). The search covered the defence database *DisNet*, the psychology database *Psychlit*, and the medical database *Medline*. Since none of these databases was found to incorporate articles from the publication *Source*, this was also perused. The search covered material available up to May, 1995. Although time since publication was not used as a criterion for exclusion of articles, individual articles deemed no longer relevant were omitted. The key words and descriptions used were:

- Helmet Mounted Sight/Display (HMS, HMD, HMSD)
- Head-up Display (HUD)
- Field of View (FOV).

These fields were used alone and together to provide a broad search base. Irrelevant articles were then pruned by individual inspection, as described above.

The resulting collection of papers has been grouped under three general headings:

- Human factors
- Design and evaluation
- Related areas.

To facilitate perusal by subject matter, entries in each section are in alphabetical order by title, followed by author, date, publication and key words. Where available, author abstracts are included. Entries are annotated (indicated by an asterisk*) where appropriate, and also where no abstract has been provided by the author.

This bibliography represents current understanding, given the present state of technology. The rapid growth in this technology indicates that domain knowledge will expand rapidly. Although further research is required for the development of HMDs, current knowledge and technology are able to provide useful working systems now. Prototype systems are already being evaluated, and it seems certain that HMDs will begin to be incorporated in aircraft cockpits in the near future. With suitable weapons systems and computing software suite, the HMS is an application of HMD technology that should endow tactical advantages in military aircraft so fitted.

## 2. HUMAN FACTORS

As most research effort to date has been directed to the engineering and development of HMD and HMS systems, the human factors aspects have received little attention until recently. However, developments have now reached a stage where there are prototypes to evaluate. Research in design of the interface with the user focuses on aspects of safety, comfort, human performance, and other useability issues. Authors frequently refer to the importance of human factors in the development of HMSs, and the need to consider the useability of such systems and the way in which these systems will impact on operators over time. Further research is required before fully operational systems become available, but human factors in HMD design is an area which is beginning to receive increasing attention.

2.1. A kinematic model for predicting the effects of helmet mounted systems
T.A. Watkins, M.S. Weiss, D.W. Call & S.J. Guccione Jr
1991
Helmet Mounted Displays and Night Vision Goggles: Advisory Group for Aerospace Research & Development (AGARD) Conference Proceedings 517
Helmet mass, modelling, human factors

A statistical study was made using head kinematic response data from a set of 70 human -X impact acceleration tests conducted at the Naval Biodynamics Laboratory. Five volunteer subjects were tested successively in three configurations: (a) no helmet, (b) helmet only, (c) helmet with weights. The peak acceleration levels ranged from 3 g to 10 g. Three kinematic responses, the X and Z components of the linear acceleration and the Y axis angular acceleration, were analyzed. These acceleration curves were fitted with polynomial splines using least squares techniques. The fitted peaks and times to peak were then regressed against sled acceleration, initial head orientation and head/neck anthropometric parameters. Statistical measures of goodness of fit were highly significant. The regression equations were used to simulate the effects of varying individual parameters (such as total head mass, peak sled acceleration, neck length, etc.).

* When a HMS system is added to a helmet, the mass is increased. The effect of this additional mass, particularly during vertical impact acceleration, needs to be ascertained. The study demonstrates a statistical modelling technique for extrapolating human head/neck kinematics to levels and types of exposure where injury would be expected.

2.2. Aircrew laser eye protection: visual consequences and mission performance
S.R. Thomas
1994
Aviation Space & Environmental Medicine. 1994 May; 65(5 Suppl): A108-15
Safety, laser eye protection (LEP), human factors

Battlefield laser proliferation poses a mounting risk to aircrew and ground personnel. Laser eye protection (LEP) based on current mature, mass-producible technologies absorbs visible light and can impact visual performance and colour identification. These visual consequences account for many of the mission incompatibilities associated with

LEP. Laboratory experiments and field investigations that examined the effects of LEP on visual performance and mission compatibility are reviewed. Laboratory experiments assessed the ability of subjects to correctly read and identify the colour of head-down display symbology and tactical pilotage charts (TPCs) with three prototype LEP visors. Field investigations included Weapons Systems Trainer (WST), ground, and flight tests of the LEP visors. Recommendations for modifying aviation lighting systems to improve LEP compatibility are proposed. Issues concerning flight safety when using LEP during air operations are discussed.

2.3. Anthropometry for HMD design
K.M. Robinette
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display, human factors, anthropometry

The importance of fit for helmet ensembles is not limited to just comfort. It impacts most other safety and performance needs of the helmets, including helmet retention, and optical and acoustical performance. The addition of optical systems to helmet ensembles increases the need for precision in fit. Helmet systems which were previously acceptable in terms of fit do not necessarily fit well enough to accommodate new performance requirements. The increased need for precision has introduced the need for better definition of human anthropometry for helmet design as well as definition of the head and helmet interface. Traditional anthropometry (human body measurements taken with callipers, or head boards, etc.) is no longer adequate. For advanced helmet systems, data on the shape, or change in the surface curvature and how this relates to helmet systems in three-dimensional space, is now a necessity. In fact, use of the old style of anthropometry can and has created problems rather than resolve them. This paper discusses some of the problems with the old methods and introduces new technologies and research which is being done to address the needs.

2.4. Binocular vision in a virtual world: visual deficits following the wearing of a head-mounted display
M. Mon-Williams, J.P. Wann & S. Rushton
1993
Ophthalmic-Physiol-Opt. 1993 Oct; 13(4): 387-91
Helmet Mounted Display (HMD), safety, binocular stress, human factors

The short-term effects on binocular stability of wearing a conventional head-mounted display (HMD) to explore a virtual reality environment were examined. Twenty adult subjects (aged 19-29 years) wore a commercially available HMD for 10 minutes while cycling around a computer generated 3-D world. The twin screen presentations were set to suit the average interpupillary distance of our subject population, to mimic the conditions of public access virtual reality systems. Subjects were examined before and after exposure to the HMD and there were clear signs of induced binocular stress for a number of the subjects. The implications of introducing such HMDs into the workplace and entertainment environments are discussed.

2.5. Colour helmet display for the tactical environment: The pilot's chromatic perspective

J.E. Melzer & K.W. Moffitt
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display, colour, human factors

The applications of colour symbology, graphics, and imagery in helmet-mounted displays have the potential to reduce workload and improve piloting performance. Unfortunately, there are three well-recognized paradigms that disallow the use of colour in helmet-mounted displays in aviation environments. We provide evidence of three corresponding paradigm shifts that encourage the use of colour in these displays. The rationales for these paradigm shifts are based on new methods of training and rehearsing, new lighting environments, and new display technologies.

2.6. Helmet mounted displays: Human factors and fidelity
P.L.N. Naish & H.J. Dudfield
1991
Advisory Group for Aerospace Research & Development (AGARD) Conference Proceedings 517
Helmet Mounted Displays (HMD), fidelity, colour, time lag, 3-D sound, human factors

Helmet mounted display (HMD) systems, of the kind able to present what has been termed virtual reality, will not be able to present a completely faithful rendering of the world. This paper shows how non-HMD technology may be used to assess the effects of this deficiency. Three aspects of the helmet mounted system are considered, and experiments are reported, which were designed to determine the degree of reality required in flyable equipment. The areas covered are time lag in the display, the need for colour and the use of 3-D sound. It is concluded that, for the parameters considered, currently available technology is able to produce stimuli which are adequate for the anticipated users of HMDs.

*Three aspects of HMDs are investigated: time lag in display, the need for colour, and the use of 3-D sound. System lag was found to be resolved when a complete synthetic environment was provided (the pilots were unable to see the outside world when using the HMD). However, when only partial immersion was used, findings suggested that lag should be kept below 300 ms. Monochrome displays were found to be adequate, although the extra potential information from colour and preference from the pilot's point of view indicated an advantage for colour in future displays. The use of 3-D sound demonstrated that auditory stimuli could add sensory fidelity to HMDs.

2.7. Helmet-mounted systems technology planning for the future
P.S. Hall & B.L. Campbell
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display (HMD) technology, human factors

Pilot workload is rapidly approaching unmanageable proportions. Programs involving sensor fusion and technologies such as Head-Up-Displays (HUDs) and Multi-Function Displays are being pursued to help the pilot reduce workload and increase their situational awareness. The Helmet-Mounted Systems Technology program office is

developing an integrated HMD system which will dramatically increase the pilot's situational awareness under all operational conditions and improve weapon system mission effectiveness. In order to accomplish this, the program must take into account requirements, current state-of-the-art and projected availability of technologies. The HMST program office uses a System Engineering approach to tie together the key technologies and interface which are required in the development of HMDs. Several of the key technologies discussed in this paper include 3-D audio, a high voltage quick disconnect connector, displays and standardized symbology.

2.8. I-NIGHTS and beyond
J.A. Stiffler & L. Wiley
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display (HMD), Human Factors issues

The United States Air Force realises there is great benefit to be gained from helmet-mounted display (HMD) technology when compared with traditional head-down displays. HMDs reduce military aircrew workload and improve their performance by mounting information display systems directly on the crew member's helmet. As the crew member concentrates outside the cockpit, information essential for successful mission execution remains within his field of view; regardless of his head position. However, mounting a display system on a helmet presents many design and safety related challenges.

The Air Force's Interim - Night Integrated Goggle and Head Tracking System (I-NIGHTS) Program identified many of the challenges associated with HMDs. Three of these challenges discussed here are fit, weight/centre of gravity, and ejection compatibility. Fitting a HMD involves more than just getting a head inside the helmet. The "fit equation" includes comfort, optical accommodation, and helmet stability. The lack of effective design in just one of these factors can negate any tactical advantage the HMD provides. HMDs also add to the weight supported by the crew member's head and neck. This weight generates significant forces during high G manoeuvres and emergency situations such as ejection. How much weight and what centre-of-gravity can the neck tolerate without injury or fatality? The Air Force I-NIGHTS Program encountered these challenges and serves as a starting point to bound their solutions.

2.9. Quick-disconnect harness system for helmet-mounted displays
P.T. Bapu, J.M. Aulds, S.P. Fuchs & D. McCormick
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Safety, Helmet Mounted Display (HMD), disconnect harness, human factors

We have designed a pilot's harness-mounted, high voltage quick-disconnect connector with 62 pins, to transmit voltages up to 13.5 kV and video signals with 70 MHz bandwidth, for a binocular helmet-mounted display system connects and disconnects with power off, and disconnects "hot" without pilot intervention and without producing external sparks or exposing hot embers to the explosive cockpit environment. We have implemented a procedure in which the high voltage pins disconnect inside a hermetically-sealed unit before the physical separation of the

connector. The "hot" separation triggers a crowbar circuit in the high voltage power supplies for additional protection. Conductor locations and shields are designed to reduce capacitance in the circuit and avoid crosstalk among adjacent circuits. The quick-disconnect connector and wiring harness are human-engineered to ensure pilot safety and mobility. The connector backshell is equipped with two hybrid video amplifiers to improve the clarity of the video signals. Shielded wires and coaxial cables are moulded as a multi-layered ribbon for maximum flexibility between the pilot's harness and helmet. Stiff cabling is provided between the quick-disconnect connector and the aircraft console to control behaviour during seat ejection. The components of the system have been successfully tested for safety, performance, ergonomic considerations, and reliability.

2.10. Second sight: Helicopter helmet-mounted displays
C. Beal
1994
International Defence Review, 12, 61-64
Helmet mounted sight (HMS) and display (HMD), human factors, comfort

*This paper discusses current and projected hardware and usage of HMDs by US and UK, and highlights the importance not only of current crashworthiness, but also consideration of future technological advances, such as more g-capable helicopters. More neck injuries occur when helmets weigh more than 1.6 kg. The paper outlines future research by US and UK, as well as raising the issue of a totally synthetic cockpit and its potential advantages in relation to poor visibility, battlefield lasers and terrain obstacles. It is suggested that the optimum FOV may be task-dependent. DRA at Farnborough is likely to explore a symbology set that leaves central vision uncluttered for target ID and display, and a peripheral zone where flight data and motion cues can be displayed. Current means of protecting pilots against the effects of ranging lasers is seen to lie in protective coatings.

2.11. The design and evaluation of fast-jet helmet mounted displays
A. Karavis & G.J.N. Clarkson
1991
Advisory Group for Aerospace Research & Development (AGARD) Conference Proceedings 517
Oxygen Mask Mounted Sight (OMMS), Helmet Mounted Sight (HMS), human factors, in flight testing

The design philosophy adopted by the Flight Systems Department of the Royal Aerospace Establishment, Farnborough for its fast-jet helmet display programme is described. Details are given of the development of two devices and the tests and methods used to meet the flight safety measurements.

The devices, a Helmet Mounted Sight (HMS) and an Oxygen Mask Mounted Sight (OMMS), each posed different problems due to their inherently different concepts. Modifications to the devices as a result of ground and air testing to meet flight safety and operational requirements are covered. The ergonomic considerations applicable to the use of these and other head mounted devices when employed as integral components of the weapons system are also discussed. In addition to describing the

physical development of the devices, a brief account is given of the display design considerations.

The results of these activities have been embodied in the RAE flight test programme which has successfully produced two helmet devices for evaluation in a combat environment. The knowledge gained from this programme is discussed in the paper together with its relevance to the successful procurement of future helmet mounted devices for combat aircraft.

*An HMS and an OMMS) are described and evaluated on human factors and safety grounds. Flight tests for both devices were performed, with the OMMS performing well under almost all conditions. Several deficiencies became apparent when the Alpha HMS was tested under similar conditions. All involved the optical design of the display, with excessive colourisation of the outside world, poor display image, and pilots being forced to view the display "patch" at all times. Human factors aspects were nominated as an area needing further development.

2.12. The human factors of helmet-mounted displays and sights
M.J. Wells & M. Haas
1992
In M.A. Karim (Ed.) Electro-Optical Displays (Part IV: Displays Issues). New York: Marcel Dekker
HMSD, FOV, comfort, human factors

*This paper discusses human factors issues relating to HMDs, such as FOV, and reports on research suggesting that performance increases with larger display FOV. The desirability of partial occlusion was also raised as an issue. To reduce the chance of the sight partially occluding visual information, the HMD could be turned off, the luminance reduced, or appropriate training could be provided. HMDs attached to helmets can mean that fit is compromised and a more individualised fit may be required. The helmet should not move, even during high-g manoeuvres, although this requirement is not currently met. Helmet design is complicated by inter-subject differences in head size and shape, eye position and line of sight, and intra-subject variations. Visual discomfort with non-colour displays and optimum colour combinations are discussed. Although research findings are sparse and somewhat inconclusive, data are presented that relate to display location. Issues regarding aiming with the head, such as the effects of a HMD on eye movements are discussed, where head "drift" of up to 3 degrees in 2 minutes can be observed.

## 3. DESIGN AND EVALUATION

Studies on the design and performance evaluation of various prototype and production HMDs are entered here. Suggestions for design of future systems are also made by some authors. The findings indicate overall that HMDs have potential for enhancing performance and reducing effort and cognitive load for pilots. Design issues include how information should be presented, what is a desirable field of view, and what potential exists for such systems to provide information to the pilot more effectively than conventional HUDs.

3.1. A comparison of three display symbology structures during an attitude maintenance task
E.E. Geiselman & R.K. Osgood
1992
Proceedings of the Human Factors Society 36th Annual Meeting - 1992
Display symbology, learning, evaluation

The present study evaluated a new aircraft attitude display concept. The new symbology format, or Theta display, was developed by integrating the features of the conventional attitude/direction indicator (ADI) and head-up attitude reference display (HUD) into a single format. Number of trials to reach a specific performance criterion and tracking performance were collected as dependent variables on an attitude maintenance task. The results show that performance and training time were better with both the Theta display and the ADI than with the HUD. The findings support the hypothesis that an attitude display formed of the integration of ADI and HUD symbology will demonstrate a performance benefit over a pure HUD format.

3.2. A helmet mounted sight evaluation exercise
P. Catling
1987
Aircrew Helmets and Helmet Mounted Devices: Proceedings
Helmet Mounted Sight (HMS), evaluation

*Advances in weapons technology are expected to lead to future air-air missiles having large off-boresight target acquisition capabilities whilst still attached to the delivery vehicle. The aiming of such weapons has led to a revival of interest in HMSs and head-position-sensing systems. This paper describes results and observations made from a recent HMS evaluation undertaken at RAE Farnborough on the Flight Systems Department Air Combat Simulator. Conclusions of the study were:

1. There were potential benefits for helmet mounted sights with off-boresight weapon aiming both by increasing opportunities for firing and reducing the opponent's opportunities, and quantitative data has shown this to be significant
2. Simple sight symbology is favoured by aircrew
3. Use of the HMS should not interfere with the pilot's ability to complete the task, in that the pilot should have confidence in its capability
4. Aircrew need to receive sufficient training in the use of helmet mounted sights and interpretation of missile firing boundaries.

3.3. A review and investigation of aiming and tracking performance with head-mounted sights
M.J. Wells & M.J. Griffin
1987
IEEE Transactions on Systems, Man, and Cybernetics, 17, 210-221
Head Mounted Sight, head aiming and tracking, evaluation

The ability to control head movements determines the performance of head-mounted sights. A literature review and the results of a number of laboratory experiments investigating head aiming and tracking performance are presented. The literature review (the results of which are included as a table) revealed that tracking performance may be degraded by in-flight conditions. The experiments measured the frequency response of the head tracking system and systematically investigated, under laboratory conditions, the effects on performance of some of the variables which may be present in an operational environment. These included off-bore sight target angle, helmet weight, seating conditions, the amplitude and axis of target motion, and reticle size and shape. It was shown that these variables had a relatively minor effect on performance. It is recommended that the influence of other relevant in-flight variables, such as the restriction due to clothing and personal equipment and the effects of whole-body vibration should be investigated.

3.4. Attitude maintenance using an off-boresight helmet-mounted virtual display
R.K. Osgood, E.E. Geiselman & C.S. Calhoun
1991
Advisory Group for Aerospace Research & Development (AGARD) Conference Proceedings 517
Helmet Mounted Display (HMD), off-boresight, performance

Helmet-mounted displays (HMDs) enable flight information to be displayed within the pilot's field-of-view, regardless of head position in the cockpit. The present research initiates the investigation of off-boresight HMD (OBHMD), which appears when the pilot's head position is greater than 20 degrees from the aircraft's boresight. Nine subjects flew a simulated, low-level, high-speed, airborne surveillance/reconnaissance mission, while monitoring a hostile adversary aircraft. The results indicate pilots were able to spend more time and look further off-boresight with an OBHMD than without one. In addition, missions with an OBHMD produced fewer terrain impacts. This research effort has demonstrated the promising performance benefits an OBHMD affords, as well as the need for further research to optimise OBHMD symbology.

3.5. Evaluation of Conformal and Body-axis Attitude Information for Spatial Awareness
D.R. Jones, T.S. Abbott & J.R. Burley II
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display, Head Up Display, testing

The traditional head-up display (HUD) used in most modern fighter aircraft presents attitude information that is both conformal to the outside world and aligned with the body-axis of the aircraft. The introduction of helmet-mounted display (HMD)

technology into simulated and actual flight environments has introduced an interesting issue regarding the presentation of attitude information. This information can be presented conformally or relative to the aircraft's body-axis, but not both (except in the special case where the pilot's line of sight is directly matched with the aircraft's body-axis). The question addressed with this study was whether attitude information displayed in an HMD should be presented with respect to the real world (conformally) or to the aircraft's body-axis. To answer this, both conformal and body-axis attitude symbology were compared under simulated air combat situations. The results of this study indicated that the body-axis concept was a more effective HMD. A detailed description of the flight task and results of this study will be presented.

3.6. Flight trial of a helmet-mounted display image stabilisation system
M.J. Wells & M.J. Griffin
1987
Aviation, Space, and Environmental Medicine, 1987 (Apr) 58(4) 319-322
Simulation, Helmet Mounted Display (HMD), vibration, evaluation

An image stabilisation system for improving reading performance with a helmet-mounted display (HMD) during whole-body vibration was tested at night in a helicopter. Six subjects read arrays of 50 numerals as quickly and as accurately as possible while flying in 3 different flight conditions. The mean reading time for each array while stationary on the ground was approximately 21 s, and the mean reading error was 0.4% without stabilisation. In-flight mean reading time increased to approximately 40 s, and reading error was 18% without the stabilisation system. Stabilising the image significantly reduced the mean in-flight reading time to approximately 25 s with a 4% reading error. Data from the flight trial support the results of previous experiments, which suggest that HMD reading performance with vibration and night viewing conditions may be inferior to performance with daylight conditions.

3.7. Helicopter integrated helmet requirements and test results
H.-D.V. Bohm & H. Schreyer
1991
Advisory Group for Aerospace Research & Development (AGARD) Conference Proceedings 517
Helmet Mounted Sight (HMS), helicopter requirements, current models, evaluation

A modern integrated helmet (IH) consists of two Image Intensifier Tubes (IIT) and two Cathode Ray Tubes (CRT) with an optical system including combiners to present the images binocularly. Additional symbology can be superimposed to the CRT- or IIT-image. An IH is a further development of a Helmet Mounted Display (HMD). A Helmet Mounted Sight (HMS) can steer a sensor platform with a thermal camera or an air-to-air missile system. The main helicopter (HC) requirements of such a system are:

- human factors
- optimized day, twilight and night optical modules
- large exit pupils, good transmission of the optical path and a large adjustment range
- fit of helmet including optimized centre of gravity (CG) and weight
- good geometrical resolution /Modulation Transfer Function (MTF) with a large Field of View (FOV)

- high focussing range of the IIT and a good S/N ratio 1 mLux
- CRT automatic brightness and contrast control
- flight symbology presentation for one or two eyes
- good static and dynamic HMS-accuracy with a large Head Motion Box (HMB)
- NBC and laser protection compatibility

*This paper describes HMS systems current at time of publication (1991), outlines methods for evaluating HMSs, and concludes that ultimately there is no completely satisfactory substitute for flight trials in evaluation of HMSs.

3.8. Helmet mounted area of interest
G. Kelly, M. Shenker & P. Weissman
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display, Field of View, design

A novel simulator display system is described. The display consists of a full field of view rear screen projection display and a narrow field of view high resolution helmet mounted display (HMD). The HMD is worn by the pilot within the projection display. The virtual image of the HMD is thus superimposed upon the real image of the projection display. This hybrid approach to building a wide field of view display takes advantage of the beneficial aspects of both projection displays and HMDs. The result is a low cost total field of view display with high resolution. Several system design problems arise in the integration of the HMD with the projection display. These issues are discussed, and include: the design of an HMD eyepiece with minimal obtrusiveness, visual blending of the HMD imagery with the projected imagery, and timing and perspective issues relating to the computer generated imagery presented by both the HMD and the projection display.

3.9. Helmet mounted display with multiple image sources
G.C. Bull
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display (HMD), multi image display, design

A helmet display that has the ability to present imagery from both NVG and FLIR sensors provides the best visual performance under a wide range of operating conditions from daylight to total darkness, because it combines the complementary advantages of the two different types of sensor. The pilot can select his sensor and operating mode to maintain imagery during natural conditions such as high humidity, thermal gradients or total darkness that would otherwise result in poor or unusable display contrast.

Design requirements for a multi image source helmet display needed for this approach are severe, since aircrew expect no compromises in image quality or physiological protection, despite the extra hardware compared with a simpler HMD or NVGs.

The system advantages are significant however, and a new helmet display that presents both intensifier and CRT imagery is being designed for both fixed and rotary wing applications.

3.10. Helmet-mounted display for the night attack mission
R.J. Whitcraft
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display, Head Up Display, design

The U.S. Army's AH-64 Apache helicopter performance during the Panama invasion and Desert Storm has silenced years of sceptical speculation regarding the utility of a visually coupled helmet mounted display (HMD) in combat. Unfortunately, in the fixed wing community, pilot night vision is limited to viewing a HUD or FLIR imagery or image intensification ($I^2$) from a helmet mounted goggle. Presently, restricted visual freedom and high head/neck ejection safety risks are accepted penalties for operating at night. Full visual freedom during night missions is a feature not yet afforded to any U.S. military fighter aircraft.

This paper will focus specifically on a candidate HMD system for the night attack mission. Included are trade off discussions relative to several specific design decisions.

3.11. Helmet-mounted display/sight tactical utility study (U)
C. Arbak, P. King, R. Jauer & E. Adam
1988
Harry G. Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio 45433-6573
Helmet mounted sight/display, performance & subjective evaluation, simulator

This report documents an evaluation of a current tactical helmet-mounted sight and display (HMS/D) in air-to-air combat. The HMS/D was evaluated in several simulated mutual support scenarios by operational F-15 pilots in the McDonnell Douglas simulator domes. Qualitative and quantitative results are described within this report as well as details of the HMS/D integration and functionality.

* Using blue force pilots in F-15 simulators, effectiveness of the HMS/D was evaluated by comparing identical missions conducted with and without the HMS/D. Performance data were collected on sensor employment, weapon usage and exchange ratios in addition to subjective workload and opinion data. A slight decrease in performance accompanied pilot's initial use of the HMS/D, while they learned how to use the new capability. Large increases in performance were found at the end of the testing period (2 weeks) with the HMD/S on, with the exchange ratio nearly doubled, while remaining constant with the HMS/D off. Pilot subjective data revealed enthusiasm for the time saved to launch AIM-9 missiles, and support for it for within-visual range targets.

3.12. Helmet-mounted systems test and evaluation process
C.P. Benedict & R.G. Gunderman
1992

Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display (HMD), evaluation

Most Department of Defence and Air Force test and evaluation regulations, supplements, pamphlets, directives, manuals and instructions deal with guidance for Engineering & Manufacturing Development programs which satisfy a validated operational user's needs. But what about other programs - those programs that focus on risk reduction, concept demonstration, and pushing the state-of-the-art to meet tomorrow's needs? Where are they to get their guidance? More specifically, how does a program manager ensure a helmet-mounted system meets all of its safety and performance criteria prior to flight testing? This paper will focus on the test and evaluation process which has been developed by the Helmet-Mounted Systems Technology Advanced Development Program Office at Wright-Patterson Air Force Base, Ohio.

3.13. Low-cost monochrome CRT helmet display
R.W. Leinenwever, L.G. Best & B.J. Ericksen
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display, cathode ray tube, evaluation, design

The goal of the cathode ray tube (CRT) helmet-mounted display (HMD) project was development and demonstration of a low-cost monochrome display incorporating see-through optics. The HMD was also to be integrated with a variety of image generation systems suitable for use with low-cost cockpit trainers and night vision goggle (NVG) training applications. A final goal for the HMD was to provide a full field of regard (FOR) using a head-tracker system. The resultant HMD design included two 1 inch CRTs used with a simple optical design of beam splitters and optical mirrors. The design provides for approximately 50% transmission and reflectance capabilities for observing the 30 degree vertical by 40 degree horizontal binocular instantaneous field of view visual image from a graphic image generator system. This design provides for a theoretical maximum of 10.8% of the CRT image source intensity arriving at the eye. Initial tests of image intensity at the eye for an average out the window scene have yielded 12 to 13 Foot Lamberts with the capability of providing approximately 130 Foot Lamberts. Invoking a software 'own ship' mask to 'blackout' the visual image, the user can monitor 'in-cockpit' instrumentation utilising the see-through characteristics of the optics. The CRTs are operated at a TV line rate with a modulation transfer function (MTF) of approximately 65%. The small beam spot size and the high MTF provide for an enhanced image display. The display electronics are designed to provide a monochrome video picture based on an RS170 video input.

3.14. Predictive nosepointing and flightpath displays for air-to-air combat
S.A. Viken & J.R. Burley II
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display (HMD), simulation, evaluation

As part of the High-Angle-of-Attack Technology Program (HATP), two integrated pictorial displays have been developed for piloted simulation evaluations and, ultimately, for flight testing on board the F/A-18 High Alpha Research Vehicle (HARV). The first concept is a nosepointing display which illustrates the range of control the pilot has over the aircraft nose. The second concept is a predictive flightpath display that allows the pilot to see how his current control inputs will affect his aircraft's future position and orientation. The development of both display concepts will be discussed, as well as the results from a piloted simulation experiment in which pilots viewed the flightpath display in a wide-field-of-view Helmet-Mounted Display (HMD) while engaged in an air-combat situation.

3.15. Quantitative helmet mounted display system image quality model
S.A. Nelson & J.A. Cox
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display, quantitative image model, evaluation

Honeywell has developed a quantitative image quality model for Helmet Mounted Display (HMD) electro-optical systems that will predict the optical performance and image quality of a given system configuration. The linear systems model includes modules for the image intensifier objective, image intensifier tube, fibre optic faceplates and tapers, charge coupled device (CCD) camera, liquid crystal display (LCD) or CRT image source, relay optics, electronic filtering and preprocessing, and a perception model for the eye. Sine wave and square wave system response are predicted via modulation transform function (MTF) calculations as well as the maximum resolution and a measurement of just noticeable differences (jnds) as perceived by the human eye. The model will allow the system designer to quickly and inexpensively evaluate complex systems tradeoffs and modifications to advanced HMD systems.

3.16. Spatial requirements for visual simulation of aircraft at real-world distances
R.S. Kennedy, K.S. Berbaum, S.C. Collyer, J.G. May & W.P. Dunlap
1988
Human Factors, 30(2), 153-161
Simulation, depth perception, orientation judgment, evaluation

To provide target image sufficiency guidelines for ground-based flight training simulators, a detection experiment examined the relative effects of contrast, resolution, and brightness on the simulated distance at which subjects could determine the orientation of another aircraft. With high resolution, luminance contrast of 25:1 produced better performance than lower contrasts. The performance at the best contrast condition was 40% better than at the poorest, whereas the best resolution condition produced only 20% better performance than the poorest. In three identical contrast conditions, higher luminance levels results in slightly better performance. In the best experimental condition, average aspect recognition thresholds for the TA-4J aircraft occurred at simulated distances > 4 miles (6.44 km), whereas in the most degraded condition, average thresholds occurred at simulated distances of 1.5 miles (2.415 km).

3.17. The advent of helmet-mounted devices in the combat aircraft cockpit: An operator's viewpoint
F.W. Chapman & G.J.N. Clarkson
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display (HMD), operators viewpoint, evaluation

With the development of the integrated combat aircraft cockpit, advanced display concepts will become increasingly important if pilot's workload is to be maintained at a suitable level for effective missions to be flown.

The Defence Research Agency (formerly FAE Farnborough) has been involved with the development of helmet-mounted display devices since the 1970s, in order to assess their suitability for integration into the modern combat aircraft cockpit.

This paper gives an operator's perspective of the helmet mounted devices trialed, covering their evolution in simulators to flight trials in fast jets. Additionally, the impact of this technology on the development of future aircraft and associated flight simulation is addressed.

3.18. The effect of field-of-view size on performance of a simulated air-to-ground night attack
R.K. Osgood & M.J. Wells
1991
Advisory Group for Aerospace Research & Development (AGARD) Conference Proceedings 517
Helmet Mounted Display (HMD), Field of View (FOV) size, performance

Five experienced fighter pilots flew a simulated, night attack, pop-up bomb delivery, with a flight simulator that had a head-mounted display. The mission was conducted with an aircraft-fixed forward looking infrared sensor (FLIR) or a head-steered FLIR. With the head-steered FLIR, the sensor image was viewed on a helmet-mounted display, whereas the aircraft-fixed FLIR was presented on a HUD. With both types of sensor, the FOV with which the subjects could see the outside world was varied from 20 to 80 degrees. The purpose of the experiment was to explore the mechanisms by which field-of-view (FOV) may affect performance, and to provide data for the determination of minimum FOV size for helmet-mounted displays (HMDs). With a head-steered sensor, subjects acquired targets earlier in the mission, (7.88 sec after pop-up vs 13.88 sec), and released their bomb at a higher altitude (1084 vs 902 ft). Increasing the size of the FOV also resulted in earlier target acquisition (7.05 sec with an 80 deg head-steered FOV, 9.55 sec with a 20 deg FOV), and higher altitude releases (1175 ft vs 843 ft). It is explained how early target acquisition allowed subjects to modify their flight paths and so position their aircraft for higher releases. Using the times to find targets as the criterion, HMD FOVs of 20 and 30 degrees were significantly worse ($p<0.05$) than FOVs of 40, 60 or 80 degrees.

*This paper explores the mechanisms by which FOV size might affect performance, and the minimum FOV size needed for HMDs. The results highlight the importance of providing a large FOV.

3.19. The effects upon visual performance of varying binocular overlap
G.K. Edgar, K.T. Carr, M. Williams, J. Page & A.L. Clarke
1991
Advisory Group for Aerospace Research & Development (AGARD) Conference Proceedings 517
Field of View (FOV), binocular overlap, Helmet Mounted Display (HMD), performance

In a helmet mounted display there is a trade-off between the binocular overlap of the images presented to each eye and the total field of view. It is therefore desirable to see whether decreasing the binocular overlap (and thus making possible a larger total FOV) adversely affects performance. This paper reports the results of four experiments examining the effects of different binocular overlaps upon performance in a visual search task, and the factors that may explain any differences in the results obtained with different overlap conditions. The results indicated that performance was poorer in all non-100% overlap conditions, and suggested that this decrement in performance could be explained by the presence of depth boundaries introduced by a disparity between the images presented to each eye.

*This paper reports a group of experiments that examined the effects of different degrees of binocular overlap within the central 15.5 degrees of the visual field. The results indicated that performance was poorer in all non-100% overlap conditions. This decrement in performance could be explained by the presence of depth boundaries introduced by a disparity between the images presented to each eye. However, the search FOV used was 15.5 degrees, which is almost certainly smaller than that provided now by most HMDs.

3.20. Towards an empirically based helmet-mounted display symbology set
E.E. Geiselman, R.K. Osgood
1993
Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting - 1993
Helmet Mounted Display (HMD), symbology, evaluation

The helmet-mounted display (HMD) affords continuous availability of critical flight information independent of head orientation. With appropriate information presented on a HMD, aircraft control can be maintained regardless of where the pilot is looking. This research addresses the development of an empirically based HMD symbol set. Three attitude formats and three altitude formats were evaluated within a composite fixed-wing HMD symbology layout. The attitude formats varied in basic form and symbol compression ratio. Symbol compression ratio is the ratio of the angle represented by the symbol to the symbol's subtended visual angle. High symbol compression results in symbols which represent large angles, and therefore have slow rate-of-motion relative to their uncompressed counterparts. The altitude symbologies were formed of both vertical scale and dial formats and included vertical velocity indicators. Subjects performed a flight-path maintenance task within sessions of differing 'real' horizon presence and orientation. The formats were evaluated under a task which was designed to require high-accuracy flight-path maintenance. This type

of task is traditionally thought to require less symbol compression. The results showed that performance was influenced by the manipulation of the attitude symbology formats. The results also suggest that symbol compression may be advantageous.

3.21. Use of a helmet-mounted matrix display for presenting energy-manoeuvrability information during simulated close combat
D.N. Jarrett
1981
Royal Aircraft Establishment, Technical Memorandum FS 396, London
Helmet Mounted Matrix Display (HMMD), evaluation

The helmet-mounted matrix display has been developed as a method of presenting information to a combat pilot so that he is not required to glance at the cockpit or at the head-up display. The energy-manoeuvrability information gives the aircraft's instantaneous manoeuvring state relative to the structural, aerodynamic and propulsive limits, and should enable a pilot to extract the optimum manoeuvring performance from his aircraft.

Since continuous visual contact with the enemy is essential in close combat the provision of this information on a helmet-mounted source may be particularly useful. However, the (in)visibility of the image against a bright sky background, the increased helmet weight and other inconveniencing counter effects, when coupled with the high attentional and physical demands of combat, may obviate any advantages of controlling the aircraft using the extra information.

This paper describes the series of exercises set up to assess the HMMD in this application. The device has been the subject of a flight trial in a light jet aircraft, and two studios have been completed in the newly-commissioned RAE Air Combat Simulator. These studies have enabled pilots to become familiar with the device and the unusual display format, before the final study, to assess their combat usefulness in a combat context, is undertaken.

3.22. Utility of off-boresight helmet-mounted symbology during a high angle airborne target acquisition task
E.E. Geiselman & R.K. Osgood
1994
SPIE Vol. 2218, 328-338
Helmet Mounted Display (HMD), Head-Up Display (HUD), symbology, evaluation

This experiment compares the utility of three off-boresight helmet-mounted display (HMD) symbology information levels for high angle target search and intercept during a simulated air-to-air engagement. The information levels included: Head-Up Display (HUD) presentation of both ownship status and target location, HUD status plus HMD target location, and HUD status plus HMD target location plus HMD ownship status. Four different attitude symbology elements were evaluated within ownship status level. The levels of the information condition variable evolved from the following questions: 1) Will HMD ownship status information help the pilot fly while searching for threats? 2) Will HMD target location information help the pilot find, intercept and track an airborne target? 3) What is the effect of combining aircraft

status and target location information within the HMD? 4) If ownship status information is helpful, are there symbology features which are more interpretable than others? The objective of this research was to determine if ownship status information within the helmet display symbology (HDS) set is necessary in an air-to-air application. The findings suggest that HDS will be advantageous, but task dependent. A strong subjective preference for including ownship status information within the HDS was found.

3.23. Visual field information in low-altitude visual flight by line-of-sight slaved helmet-mounted displays.
A.J. Grunwald & S. Kohn
1994
IEEE Transactions on Systems, Man, and Cybernetics, 1994, 24(1), 120-134

The pilot's ability to derive control-oriented visual field information from teleoperated helmet-mounted displays in nap-of-the-earth flight is investigated in this paper. The visual field with these types of displays, commonly used in Apache and Cobra helicopter night operations, originates from a relatively narrow field-of-view forward looking infrared radiation (FLIR) camera, gimbal-mounted at the nose of the aircraft and slaved to the pilot's line of sight, providing a wide-angle field of regard. Pilots have encountered considerable difficulties in controlling the aircraft by these devices. The experimental simulator results presented here indicate that part of these difficulties can be attributed both to the narrow camera field of view and to head/camera slaving system phase lags and errors. In the presence of voluntary head rotation, these shortcomings are shown to impair the control-oriented visual field information vital in vehicular control, such as the perception of the anticipated flight path or the vehicle yaw rate. Since the pilot will tend to minimize head rotation in the presence of slaving system imperfections, the full wide-angle field of regard of the line-of-sight slaved helmet-mounted display is not always fully utilized. The findings in this paper are valid for a general class of head-slaved displays which are used in teleoperation and virtual environments and in which correct self-motion estimation is an essential part of the operator task.

*This paper reports a study that used 9 aerospace undergraduates (aged 19-24 yrs) to investigate pilots' ability to derive control-oriented visual field information from line-of-sight slaved HMDs in nap-of-the-earth flight. Results indicate that part of these difficulties can be attributed both to the narrow camera FOV and to head/camera slaving system phase lags and errors. Since the pilot will tend to minimise head rotation in the presence of slaving system imperfections, the full wide-angle field of regard of the line-of-sight slaved HMD is not always fully used, and search performance and spatial orientation will be impaired.

## 4. RELATED AREAS

Entries in this section deal principally with matters that relate to HMD design and includes issues such as complete immersion under so-called virtual reality (VR) and virtual environment (VE) régimes. The use of HMDs at night also relates to visual performance with night vision goggles (NVGs). While some of these studies may not deal directly with HMSs, they are included here to provide further insights into ways in which HMD design can benefit from research findings in related areas.

4.1. A literature survey for virtual environments: Military flight simulator visual systems and simulator sickness
R. Pausch, T. Crea & M. Conway
1992
Presence, 1(3).
Virtual environments (VE), simulation

Researchers in the field of virtual environments (VE), or virtual reality, surround a participant with synthetic stimuli. The flight simulator community, primarily in the U.S. military, has a great deal of experience with aircraft simulations, and VE researchers should be aware of the major result in this field. In this survey of the literature, we have especially focused on military literature that may be hard for traditional academics to locate via the standard journals. One of the authors of this paper is a military helicopter pilot himself, which was quite useful in obtaining access to many of our references. We concentrate on research that produces specific, measured results that apply to VE research. We assume no background other than basic knowledge of computer graphics, and explain simulator terms and concept, as necessary. This paper ends with an annotated bibliography of some harder to find research results in the field of flight simulators:

- the effects of display parameters, including field of view and scene complexity;
- the effect of lag in system response;
- the effect of refresh rate in graphics update;
- the existing theories on causes of simulator sickness; and
- the after effects of simulator use.

Many of the results we cite are contradictory. Our global observation is that with flight simulator research, like most human-computer interaction research, there are very few 'correct' answers. Almost always, the answer to a specific question depends on the task the user was attempting to perform with the simulator.

4.2. Display & sight helmet system: Operational analysis
Elbit Co Pty
1992
Elbit Co Pty
Elbit Display & Sight Helmet System, combat model

*This unpublished paper from the Elbit Company describes a model of air-to-air encounter produced, with probability values at each discrete state of the chain provided by experienced pilots. The Elbit Display And Sight Helmet (DASH) system generally improved performance during 1 vs 1 scenarios, although it was in 4 vs 4

encounters that the DASH's impact was greatest. Even a small degree of superiority gained in the 1 vs 1 encounter "snowballed" to a numerical superiority of greater magnitude. This highlighted the importance of establishing 1 vs 1 superiority.

4.3. Distance estimation training with night vision goggles under low illumination
J.D. Reising & E.L. Martin
1995
Air Force Material Command, Brooks Air Base, Texas
Night Vision Goggles (NVG), distance perception, training

Aircrews have reported significant problems in depth perception and distance estimation with night vision goggles (NVGs). The purpose of this experiment was to examine the value of a simple training procedure as a means of reducing errors. A pre/post-test design was used in which distance estimates for a training group and control group were compared. The results revealed significant reductions in errors and variability following exposure to the training procedure. No significant reduction in errors and variability occurred with the control group. These results are consistent with a preliminary experiment using NVGs and earlier research using unaided vision. Issues for future research are also discussed.

*It is noted in this paper that little research focuses on the acquisition of visual distance knowledge that pilots appear to obtain from various experiences. Judgments of depth perception are often compromised with NVGs. Gibson & Bergman's (1954) classic study is referred to, where corrective feedback improved absolute distance estimation. It was proposed that a learning component also existed with NVG usage. In the present study, training consisted of a perceptual calibration procedure, where subjects observed targets with known distances. It was found that accuracy approximately doubled with training while performance with the control group receiving no feedback remained constant. The results also revealed a tendency to underestimate the egocentric distances and to be more accurate with exocentric distances.

4.4. Helmet mounted displays: Are we jumping the gun?
C. Beal & B. Sweatman
1994
International Defense Review, 9, 69-75

*This paper reviews attributes of eight demonstration and one production (Elbit DASH) HMDs. Four major technological hurdles needing to be overcome are nominated:

- image generation and processing
- optics
- helmet tracking systems
- helmet ergonomics.

4.5. Intensified CCD sensor applications for helmet-mounted displays
L.H. Gilligan

1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Helmet Mounted Display, on-helmet sensor, ICCD

Present state-of-the-art technology in intensified solid state (ICCD) video cameras renders these sensors an apt candidate for use as an "on-helmet" sensor in helmet mounted display application. This overview paper establishes the usefulness of ICCD in terms of parametric performance and suggests future trends and potential new capabilities.

4.6. Operation of the Elbit display and sight helmet (DASH) in the high off-boresight seeker (HOBS) test program F/A-18D Hornet
Elbit Co Pty
1992
Elbit Co Pty
Elbit Display and Sight Helmet (DASH), features

*This unpublished paper from the Elbit Company describes in detail the features of the Elbit Display and Sight Helmet (DASH). The DASH displays the following:
(a) Helmet line of sight heading
(b) Helmet line of sight elevation
(c) Aiming cross
(d) AOA, Mach, G
(e) Airspeed
(f) Aircraft heading
(g) Altitude
(h) Radar/barometric altitude suffix

4.7. The realities of using visually coupled systems for training applications
R.S. Kalawsky
1992
Helmet-Mounted Displays III, Thomas M. Lippert, Editor, Proc. SPIE 1695
Visual Cockpit, complete immersion, virtual reality (VR)

Visually coupled system developments have led to the concept of a Virtual Cockpit known as the Super Cockpit. Advances in Super Cockpit enabling technologies has resulted in an exciting spin-off called Virtual Environments or Virtual Reality. Press releases claim almost limitless possibilities for this technology. Unfortunately the level of technology required to achieve actual Virtual Reality (VR) has still to be realised. Inspection of current VR systems readily reveals several fundamental problems. However, by fully understanding the limitations in VR technology and the complex human factors interface it is possible to apply VR to many applications, especially in training. In order to create virtual reality the technology limitations must be understood and overcome. Whatever solution is eventually derived, it must fully address the complex human factors issues.

This paper will review the realities of virtual environments in terms of the limitations in technology and apparent lack of human factors understanding. The establishment and development of the British Aerospace Virtual Cockpit Facility at Brough, one of the

UK's largest Virtual Environmental laboratories has provided an insight into the key issues of virtual reality. These facilities are engaged in the evaluation of fundamental engineering and human factors issues. In order to illustrate the major problems and how they can be overcome, the results of some of these studies are given.

## 5. GLOSSARY

| | |
|---|---|
| ADI | Attitude/Direction Indicator |
| AGARD | Advisory Group for Aerospace Research and Development |
| CCD | Charge Coupled Device |
| CG | Centre of Gravity |
| CRT | Cathode Ray Tubes |
| DASH | (Elbit) Display And Sight Helmet |
| DRA | Defence Research Agency |
| FOV | Field Of View |
| HARV | High Alpha Research Vehicle |
| HATP | High Angle of attack Technology Program |
| HC | HeliCopter |
| HMB | Head Motion Box |
| HMD | Helmet Mounted Display |
| HMMD | Helmet Mounted Matrix Display |
| HMS | Helmet Mounted Sight |
| HOBS | High Off-Boresight Seeker |
| HUD | Head-Up Display |
| IH | Integrated Helmet |
| IIT | Image Intensifier Tubes |
| LCD | Liquid Crystal Display |
| MTF | Modulation Transfer Function |
| NVG | Night Vision Goggles |
| OMMS | Oxygen Mask Mounted Sight |
| VE | Virtual Environment |
| VR | Virtual Reality |

## 6. ACKNOWLEDGEMENTS

This annotated bibliography was prepared by the Air Operations Division, Aeronautical and Maritime Research Laboratory, Fishermens Bend, Victoria, to provide background information for a simulation study of a helmet mounted sight system for the RAAF, whose sponsorship is gratefully acknowledged.

**Annotated Bibliography of Helmet Mounted Sight Systems**
Saliba, A.J. and Meehan, J.W

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1. PRIVACY MARKING/CAVEAT (OF DOCUMENT)

2. TITLE

Annotated Bibliography Of Helmet Mounted Sight Systems

3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION)

| | |
|---|---|
| Document | (U) |
| Title | (U) |
| Abstract | (U) |

4. AUTHOR(S)

A. J. Saliba and J.W. Meehan

5. CORPORATE AUTHOR

Aeronautical and Maritime Research Laboratory
PO Box 4331
Melbourne Vic 3001

| 6a. DSTO NUMBER | 6b. AR NUMBER | 6c. TYPE OF REPORT | 7. DOCUMENT DATE |
|---|---|---|---|
| DSTO-GD-0097 | AR-009-740 | General Document | January, 1996 |

| 8. FILE NUMBER | 9. TASK NUMBER | 10. TASK SPONSOR | 11. NO. OF PAGES | 12. NO. OF REFERENCES |
|---|---|---|---|---|
| M1/9/179 | ADA 94/253 | DGFD(AIR) | 23 | 42 |

13. DOWNGRADING/DELIMITING INSTRUCTIONS

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16. DELIBERATE ANNOUNCEMENT

No limitations

17. CASUAL ANNOUNCEMENT Yes

18. DEFTEST DESCRIPTORS

helmet mounted displays, helmet mounted sights, human factors, bibliographies, performance, evaluation, design, cockpit displays, ergonomics, head up displays

19. ABSTRACT

A search of literature was conducted on helmet mounted sights (HMSs) and related helmet mounted displays (HMDs). The result was 42 entries that are grouped under broad subject headings of human factors, design and evaluation, and other related areas. Human factors deals with issues relating to human performance with HMSs and HMDs. Design and evaluation covers work that is focused more on the helmet systems. Work in related areas includes material that fits neither of the other categories, but which is relevant. Entries are accompanied by an abstract, annotation, or both. This bibliography represents present understanding of issues involved with the current state of technology. Rapid growth in computer technology suggests that developments in this area will accelerate rapidly, indicating a need for maintaining commensurate research effort in human performance in the virtual environments that this technology is providing.